The Post-crisis Slump in Europe: A Business Cycle Accounting Analysis*

Florian Gerth† Keisuke Otsu‡

March 25, 2017

Abstract

This paper analyses the Post-crisis slump in 30 European economies during the 2008Q1 - 2014Q4 period using the Business Cycle Accounting (BCA) method á la Chari, Kehoe and McGrattan (2007). We find that the deterioration in the efficiency wedge is the most important driver of the European Great Recession and that this adverse shock persists throughout our sample. Moreover, we find that countries with higher growth in nonperforming loans feature a smaller decline in efficiency wedges. These findings support the emerging literature on resource misallocation triggered by financial crises.

Keywords: Great Recession, Business Cycle Accounting, European Economy

JEL Code: E13, E32

*We are grateful to the editor, the anonymous referee, Sylvain Barde, Pedro Brinca, Jagjit Chadha, Patrick Minford, Claudio Morana, Jakub Muck, and participants of the University of Kent MaGHiC PhD workshop, the 47th MMF Annual Conference, and the SCE 22nd International Conference on Computing in Economics and Finance and seminars at the University of Barcelona and RWI Essen for their helpful comments.

†School of Economics, University of Kent, Canterbury, Kent, CT2 7NP, United Kingdom. Email: F.Gerth@kent.ac.uk , Tel. +44-1227-824437.

‡School of Economics and MaGHiC, University of Kent, Canterbury, Kent, CT2 7NP, United Kingdom. Email: K.Otsu@kent.ac.uk , Tel. +44-1227-827305.

1 Introduction

While more than seven years has passed since the onset of the Great Recession, European countries have not shown any signs of recovery. Moreover, there is few consensus on why this is the case. This paper quantitatively analyses the post-crisis slump in Europe from the beginning of 2008 until the end of 2014 with the Business Cycle Accounting (BCA) method á la Chari, Kehoe and McGrattan (2007).

BCA is a useful tool to decompose business cycle fluctuations into their contributing factors. The idea behind this approach is to lead researchers into the direction of classes of economic models that give detailed understanding behind economic (mis)performances. The accounting procedure is conducted as follows. First, several exogenous frictions called wedges are defined in equilibrium conditions of a standard Real Business Cycle model. Second, the stochastic process of these wedges are structurally estimated using Bayesian estimation methods. Third, the wedges are backed out using data and the model solution. Finally, the wedges are put back into the model, one by one, in order to quantify their relative importance over the drop in output, consumption, investment, and labor.

The BCA method has been widely applied to the analysis of specific business cycles episodes in various countries. Chari, Kehoe and McGrattan (2007) focus on the Great Depression and early 1980s recession in the U.S. Saijo (2008) investigates the Great Depression in Japan. Klein and Otsu (2013) compares the interwar Great Depressions in the U.S. and Western Europe. Kersting (2008) studies the UK recession in the 1980s. Kobayashi and Inaba (2006) studies the Great Depression and lost decade in Japan. Chakraborty (2009) investigates the sources of the boom and bust in Japan during the 1980s and 1990s. Lama (2011) focuses on output drops in Latin America during the 1990s. Otsu (2010a) studies the 1998 crises in East Asia. Cho and Doblas-Madrid (2013) compare 23 financial crisis episodes over the 1980-2001 period. Chakraborty and Otsu (2013) analyze the growth episodes of the BRICS economies. Brinca (2014) studies 22 OECD countries over the 1970-2011 period. Most of these studies show that efficiency and labor wedges are important in accounting for output fluctuations.

The outbreak of the 2008 financial crisis led to a rash of research on the nature of financial crises in quantitative macroeconomic models. Khan and Thomas (2013) and Buera and Moll (2015) construct models with heterogeneous firm level productivity in which credit shocks to borrowing constraints lead to misallocation of production factors across firms. Gertler and Kiyotaki (2010), Gertler and Karadi (2011) and Gertler, Kiyotaki and Queralto (2012) construct models with financial frictions in the banking sector which constrains investment. Jermann and Quadrini (2012) constructs a model with a working capital constraint on employment where an increase in the firms borrowing cost increases the cost of labor. These models, through the lens of business cycle accounting, can be mapped into prototype models with efficiency, investment and labor wedges. We can therefore use our business cycle accounting results to infer the channel through which the financial crises have operated.

Our paper is closely related to Brinca, Chari, Kehoe and McGrattan (BCKM 2016) which investigates the Great Recessions in 24 OECD countries using the BCA method. While BCKM (2016) investigate the decline in output between the respective peak and troughs in 24 OECD countries, we analyze the cross-country differences of the post-crisis slump in 30 European countries over the 2007Q4-2014Q4 period. Moreover, while we share 16 out of the 24 countries in their sample, we have a wider coverage of European countries in our sample which enables us to conduct a cross-sectional analysis on the BCA results. Our main value added to BCKM (2016) is that we investigate the regional differences and provide a potential explanation to the BCA result by studying the relationship between the drops in wedges and financial variables in a cross-country framework.

The main findings of this paper are that the distortion in the representative firm's production function (the efficiency wedge) is mainly responsible for the prevalent output decline in Europe beginning at the onset of the crisis in the early 2008. This is consistent with the literature that blames the misallocation effect of credit crunches for aggregate productivity loss. We further find that a subset of financial variables is significantly related to the cross-country differences in the magnitude in the wedge distortions. Countries with a smaller decline in market capitalization, higher level and growth in non-performing loans relative to total loans and smaller decline in house prices experienced less deterioration in efficiency wedges. Also, countries with less decline in the housing price index experienced less deterioration in labor wedges.

The remaining of this paper is structured as follows: The second section describes the data. The third section introduces the BCA model. The fourth section presents the quantitative analysis. In section 5 we discuss possible variables that commove with predicted output performances. The last section

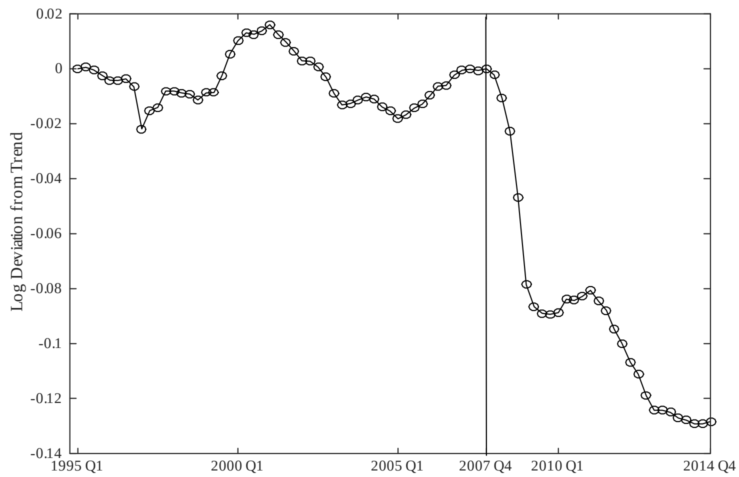

Figure 1: Detrended Aggregate European Output per Adult

concludes.

2 Data

Figure 1 presents the aggregate quarterly log per capita output in 30 European countries over the 1995Q1-2014Q4 period detrended by the average growth rate over the 1995Q1-2007Q4 period. The figure clearly shows the devastating impact of the financial crisis on European output in 2008. Moreover, the economy is showing no sign of recovery with a double dip after 2011.

The countries in our sample are listed in Table 1.[1] We also report the detrended output decline between 2007Q4 and 2014Q4 for each country in percentage points. The only country that seems to have recovered from the crisis is Malta with an output growth of 16.61%. All other countries have not come back to their pre-crisis trend level. Clearly, some countries experienced greater declines in per capita output than others. Countries which suffered the most are Greece (56.1% drop), Estonia (48.7% drop) and Latvia (48.6%).

[1] Full data is not available for Croatia.

12 output 30 countries experienced an output drop greater than 25% and 23 experienced one greater than 15%. In the following we look into country specific data in order to compare the experiences of each country.

Table 1: Sample Countries and Output Drop

Euro Area:					
Austria	14.6	Belgium	13.2	Cyprus	29.8
Estonia	48.7	Finland	34.3	France	10.9
Germany	4.7	Greece	56.1	Ireland	29.2
Italy	23.8	Latvia	48.6	Luxembourg	27.9
Malta	-16.6	Netherlands	18.0	Portugal	19.1
Slovakia	25.4	Slovenia	35.3	Spain	25.4
European Union: Euro Area plus					
Bulgaria	24.8	Czech Republic	15.2	Denmark	13.6
Hungary	23.7	Lithuania	37.2	Poland	20.3
Romania	16.9	Sweden	15.3	United Kingdom	15.3
Europe: European Union plus					
Iceland	29.1	Norway	20.3	Switzerland	8.7

Quarterly data for output, consumption, investment, total hours worked (as a measure for labor input) is obtained through Eurostat, using the European System of Accounts (ESA) 2010 data. The data coverage goes from 1995Q1 up to 2014Q4. The expenditure data for output, consumption and investment are obtained in 2010 chained Euros. For periods in which ESA 2010 expenditure data is missing, the series is extrapolated using the ESA 2005 expenditure data. For periods in which ESA 2010 total hours data is missing, ESA 2005 data is used whenever possible. If neither quarterly total hours worked exists in the ESA 2010 nor in the ESA 2005 data set, we use quarterly employment and hours worked per worker data from the OECD Economic Outlook. Population is defined as the number of people aged 15-64 years old and is obtained through Eurostat. Since the population data was only available in annual terms we have interpolated them using a cubic spline method.

In order to match data to the model, we make several data adjustments following Chari, Kehoe and McGrattan (2007) and Brinca, Chari, Kehoe and McGrattan (2016). Private consumption expenditure in the data consists of expenditure on non-durable goods, semi-durable goods, durable goods, and services. The expenditure on non-durable goods, semi-durable goods, and services are included in consumption while durable goods expenditures are considered as investment. We impute service flows from durable stock and add them to consumption and total output.[2] We subtract sales tax from consumption expenditures and output.[3] In sum, our consumption includes expenditure on non-durables, semi-durables, services, and the imputed service flow from durable stock less the sales tax on consumption. Our investment contains gross domestic capital formation and the expenditure on durable goods less the sales tax on the purchases of durables. Finally, our output consists of GDP and the imputed service flow from durable stock less the sales tax.

In order to define a stationary economy, all variables are detrended by their respective growth trends:

$$y_t = \frac{Y_t}{N_t \Gamma_t}, c_t = \frac{C_t}{N_t \Gamma_t}, i_t = \frac{I_t}{N_t \Gamma_t}, h_t = \frac{H_t}{N_t},$$

where Y_t is total output, C_t is consumption, I_t is investment, H_t is labor input, N_t is the adult population growing at the rate $(1+n)$, and Γ_t is the trend component of labor augmenting technical progress growing at the rate $(1+\gamma)$, which we proxy with the average per adult output growth rate.

Figure 2 shows the cross-country mean of the time series of per capita output y, consumption c, investment i, and labor input h from 2007Q4 (the last period before the onset of the crisis) until 2014Q4. All data are logged and then linearly detrended except for labor input which is demeaned as it is assumed to have no trend.[4] We proxy the rate of labor augmenting technical progress with the average growth rate of output per adult over the

[2]In countries that report expenditure on durables only at the annual frequency, Belgium, Iceland and Ireland, we apply the Chow-Lin frequency conversion method based on Maximum Likelihood and the Kalman filter using the quarterly data of GDP and gross domestic capital formation. For Czech, Poland, and Romania, we used the frequency converted series to extrapolate the quarterly data for several missing periods. For Switzerland, we could not find any data for expenditures on durables so we used total consumption expenditure as consumption.

[3]We use the tax to GDP ratio of Taxes on Production and Imports from Eurostat to compute the tax level. Then we use the consumption expenditure share of durables in order to subtract this portion of the tax from investment and the remaining from consumption.

[4]Total hours worked is only detrended by dividing through per adult population since its only trend comes from the growth in population and not from the growth in labor augmenting technical progress.

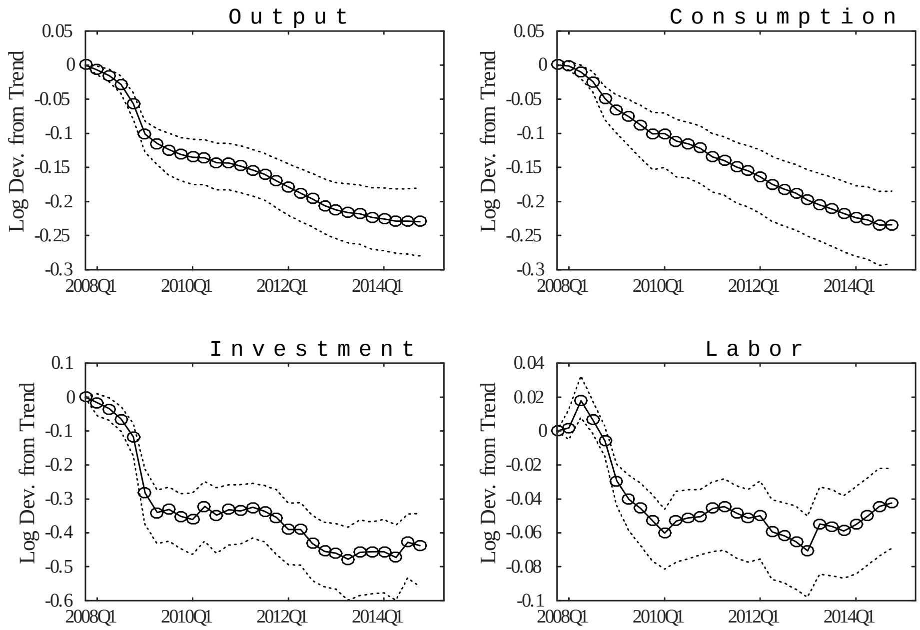

Figure 2: Detrended Average European Data

1995Q1-2007Q4 period.[5] The solid line with circular markers is the observed mean value of the data variable, the dashed line represents the 95% bootstrap confidence interval.

Notice that the post crisis decline in output is considerably larger than the aggregate output decline in Figure 1. This indicates that there are several small countries with large per capita output drops. For convenience we will use the simple mean figures throughout this paper.

We can clearly see that output and consumption start a rapid decline in the first few quarters of the crisis. This decline continues until the end of the observation period in the last quarter of 2014. It is important to recognize

[5]By definition the growth rate of per capita output must be equal to the growth rate of labor augmenting technical progress along the balanced growth path. We assume the economies are on the balanced growth path over the 1995Q1-2007Q4 period so that the detrended output has a zero growth rate on average during this period. Therefore, the average growth rate of output per capita and that of the labor augmenting technical progress during this period must be equal.

that both variables do not show any sign of recovery throughout the entire period. At the end of 2014, average output in Europe lost almost 24% and consumption lost almost 25% of its pre-crisis level. For both cases neither the level nor the growth rate has recovered to its pre-crisis trend, hence, a recovery from the initial shock and end of the Great Recession is still wishful thinking.

Investment on the other hand shows an even more radical picture. It drops in the first six periods of the crisis by almost 35%, more than three times the size of the drop in output during the same period. It temporarily settles down after that just to drop by another 20% in mid-2011. At the beginning of 2013 it settles down again and remains at this level of more than 40% below trend. As seen by the confidence interval, some countries even experience a drop in investment expenditures of almost 60% compared to their pre-crisis trend level.

Labor input, as measured by total hours worked per capita, increases almost 2% at the beginning of the crisis. After this increase it goes into steep decline until the beginning of 2013 and remains at the level of around negative 6% until the end of the observation period.

3 Benchmark Prototype Model

The benchmark prototype model follows Chari, Kehoe and McGrattan (2007) with 1) a representative household, that maximizes its lifetime utility gained from consumption and leisure, 2) a representative firm that maximizes profits by periodically choosing how much labor to hire and capital to rent, and 3) the government sector that collects distortionary taxes in order to finance its exogenous expenditure.

3.1 Household's Problem

The representative consumer maximizes expected lifetime utility:

$$E_t \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - h_t)$$

where E is the expectations operator for all future values in time t, and $\beta \in$ (0,1) is the discount factor for future utility.

The period utility depends on consumption c_t, and leisure $1 - h_t$:

$$u(c_t, 1 - h_t) = \psi \ln c_t + (1 - \psi) \ln(1 - h_t), \tag{1}$$

where ψ is a preference weight parameter.

The household's budget constraint is

$$(1 - \tau_{h,t}) w_t h_t + r_t k_t + \pi_t + \tau_t = c_t + (1 + \tau_{i,t}) i_t, \tag{2}$$

where w_t is the wage rate, r_t is the real rental rate, k_t is the capital stock, π_t is the firm's profits paid back to the household as the dividends to the owner of the firm, τ_t is the lump-sum transfer paid by the government, and i_t is gross capital investment. $\tau_{h,t}$ and $\tau_{i,t}$ are the tax rates on labor income and investment, respectively.

The capital stock follows the law-of-motion:

$$\Lambda k_{t+1} = i_t + (1 - \delta) k_t \tag{3}$$

where δ is the depreciation rate and Λ is the growth trend of the economy which consists of population growth and productivity growth.

3.2 Firm's Problem

The firm maximizes profits:

$$\pi_t = y_t - w_t h_t - r_t k_t \tag{4}$$

by choosing labor input h_t and capital k_t, and thereby determining output y_t. The production function is assumed to be Cobb-Douglas:

$$y_t = k_t^{\theta} (z_t h_t)^{1-\theta} \tag{5}$$

where z_t is the labor augmenting technical shock and θ is the capital intensity.

3.3 Government

The government sector collects taxes in order to finance its expenditure and rebates the remainder to the consumer in form of lump-sum transfers. Hence, the government's budget constraint is:

$$\tau_{h,t} w_t h_t + \tau_{i,t} i_t = \tau_t + g_t \tag{6}$$

where g_t stands for government consumption.

If we substitute the government budget constraint (6) and the firm's problem (4) into the household budget constraint (2) we obtain the resource constraint:

$$y_t = c_t + i_t + g_t. \tag{7}$$

3.4 Wedges

For convenience, we define efficiency, government, investment and labor wedges as follows.[6] The efficiency wedge is defined as:

$$\omega_{e,t} = \left(\frac{y_t}{k_t^{\theta} h_t^{1-\theta}} \right)^{\frac{1}{1-\theta}} = z_t,$$

which is equivalent to the labor augmenting technical shock.[7]

The government wedge is defined as the difference between the goods produced in an economy, and the goods available to its private agents:

$$\omega_{g,t} = y_t - c_t - i_t = g_t,$$

which is equivalent to government purchases.

The investment wedge is defined as a friction in the capital Euler equation

[6] We define the wedges such that they can be linearized exactly as all other variables. The notation is slightly different from that in the original CKM (2007) paper. Nonetheless, they are quantitatively equivalent.

[7] CKM (2007) defines the production function as

$$y_t = A_t k_t^{\theta} h_t^{1-\theta}$$

but in their technical appendix the authors define efficiency wedges as labor augmented technical shocks z_t where

$$y_t = k_t^{\theta} \left(z_t h_t \right)^{1-\theta}$$

We follow the definition of the technical appendix.

$$\omega_{i,t} = \frac{\Lambda}{\beta} E\left[\frac{\frac{c_{t+1}}{c_t}}{\theta\frac{y_{t+1}}{k_{t+1}} + \frac{1-\delta}{\omega_{it+1}}}\right] = \frac{1}{1+\tau_{i,t}}, \tag{8}$$

which drives a wedge between the inter-temporal marginal rate of substitution of current consumption to future consumption and the marginal return to investment.

The labor wedge is defined as a friction in the labor market equilibrium condition

$$\omega_{h,t} = \frac{\frac{1-\psi}{\psi}\frac{c_t}{1-h_t}}{(1-\theta)\frac{y_t}{h_t}} = 1 - \tau_{h,t},$$

which drives a wedge between the intra-temporal marginal rate of substitution of leisure to consumption and the marginal product of labor.

3.5 Equilibrium

A competitive equilibrium in this model is a sequence of prices $\{w_t, r_t\}_{t=0}^{\infty}$ and quantities $\{y_t, c_t, i_t, h_t, k_{t+1}\}_{t=0}^{\infty}$ and wedges $\{\omega_{e,t}, \omega_{g,t}, \omega_{i,t}, \omega_{h,t}\}_{t=0}^{\infty}$ such that:

1. The household maximizes utility taking$\{w_t, r_t, \omega_{g,t}, \omega_{i,t}, \omega_{h,t}\}_{t=0}^{\infty}$ and an initial value of k_0 as given;

2. The firm maximizes profits taking $\{w_t, r_t, \omega_{e,t}\}_{t=0}^{\infty}$ as given;

3. Labor and capital markets clear for every period;

4. The government budget constraint (6) and resource constraint (7) hold for every period; and

5. The exogenous variables follow a stochastic process.

$$\begin{aligned} \widetilde{\omega_{t+1}} &= P\widetilde{\omega}_t + \varepsilon_{t+1} \\ \varepsilon &\sim N(0, V) \end{aligned} \tag{9}$$

where $\omega_t = (\omega_{e,t}, \omega_{g,t}, \omega_{i,t}, \omega_{h,t})'$, P is a 4×4 transition matrix, and $\varepsilon_t = (\varepsilon_{e,t}, \varepsilon_{g,t}, \varepsilon_{i,t}, \varepsilon_{h,t})'$ are innovations that have a standard normal distribution with zero-mean and a variance-covariance matrix V.[8] The "$\sim$" throughout this paper is a notation for the log deviation from the trend of each variable.

Formally the equilibrium can be represented in a state where all of the following equations hold:

$$\frac{1-\psi}{\psi}\frac{c_t}{1-h_t} = \omega_{h,t}(1-\theta)\frac{y_t}{h_t},$$

$$\frac{\Lambda}{\omega_{i,t}} = \beta E\left[\frac{c_t}{c_{t+1}}\left(\theta\frac{y_{t+1}}{k_{t+1}}+\frac{1-\delta}{\omega_{i,t+1}}\right)\right],$$

$$y_t = c_t + i_t + \omega_{g,t},$$

$$y_t = k_t^{\theta}\left(\omega_{e,t}h_t\right)^{1-\theta},$$

$$\Lambda k_{t+1} = i_t + (1-\delta)k_t.$$

3.6 Equivalence Results and The Financial Crisis

A useful interpretation of the business cycle accounting model is that it nests several classes of detailed models. In context of the recent financial crisis, Buera and Moll (2015) shows that we can map several credit crunch recession models into prototype models with efficiency, investment and labor wedges. The common feature of these models are that each firm i faces a constraint on external finance which states that the borrowing d cannot exceed a fraction of capital k:

$$d_{i,t+1} \leq \theta_t k_{i,t+1}.$$

A tightening of the borrowing constraint in the form of a drop in θ represents a credit crunch. Business cycle accounting is therefore useful in detecting the channel through which the credit crunch could have operated.

[8] The variance-covariance matrix is unrestricted in the sense that it allows for simultaneous correlations of innovations.

3.6.1 Efficiency Wedge, $\omega_{e,t}$

The efficiency wedge is equivalent to the Solow residual which is often referred to as "productivity". This can include technological progress driven by inventions and innovations, factor utilization, accumulation of human capital and general production efficiency. This can also include allocative efficiency of the aggregate economy. Chari, Kehoe and McGrattan (2007) shows that a model with input financing frictions, in which heterogeneous credit spreads faced by intermediate goods producers lead to suboptimal resource allocation, can be mapped into a prototype model with efficiency wedges. Buera and Moll (2015) shows that a model with heterogeneous firm productivity and external borrowing constraints can be mapped into a prototype model with efficiency wedges.[9] In their model, a tightening of the borrowing constraint reduces the amount the most productive firms can borrow and increases resources allocated towards less productive firms which would otherwise have been lent to the productive firms.

3.6.2 Investment Wedge, $\omega_{i,t}$

The investment wedge is defined as distortionary tax on investment expenditures. However, various market distortions and shocks can be observationally equivalent to investment wedges in a business cycle accounting context. Chari, Kehoe and McGrattan (2007) shows that a model with financial frictions arising from costly state verification as in Bernanke, Gertler and Gilchrist (1999) can be mapped into a prototype model with investment wedges.[10] Inaba and Nutahara (2009) shows that a financial friction model a la Carlstrom and Fuerst (1997) can be mapped into a prototype model with investment wedges. Klein and Otsu (2013) shows that a model with expectational shocks to future output can be mapped into a prototype model with investment wedges. Brinca, Chari, Kehoe and McGrattan (2016) shows that a model with financial frictions arising from a bank collateral constraint as in Gertler and Kiyotaki (2010) can be mapped into a prototype model with investment wedges. In their model, they assume an exogenous decline in the quality of capital as the direct financial shock. Buera and Moll (2015)

[9] In their detailed model, investment and labor wedges also exist between the household and entrepreneurs.

[10] Chari, Kehoe and McGrattan (2007) show that a model based on Bernake, Gertler and Gilchrist (1999) maps into a prototype model with taxes on capital income rather than taxes on investment expenditure.

shows that a model with heterogeneous investment costs among firms can be mapped into a prototype model with investment wedges. In their model, a tightening of the borrowing constraint will prevent resources to flow into the firm with lowest investment cost and hence increase the marginal cost of investment.

3.6.3 Labor Wedge, $\omega_{h,t}$

The labor wedge is defined as distortionary tax on labor income. However, various market distortions can manifest themselves as labor wedges. Chari, Kehoe and McGrattan (2007) shows that a model with nominal wage rigidity and monetary shocks can be mapped into a prototype model with labor wedges. Klein and Otsu (2013) shows that a model with time varying labor union bargaining power as in Cole and Ohanian (2004) can be mapped into a prototype model with labor wedges. Otsu (2010a) shows that a model with a working capital constraint on labor such as Jermann and Quadrini (2012) in which an increase in labor cost due to rising credit spreads can be mapped into a prototype model with labor wedges. Buera and Moll (2015) shows that a model with labor search frictions and heterogeneous recruitment costs among firms can be mapped into a prototype model with labor wedges. In their model, a tightening of the borrowing constraint will prevent resources to flow into the firm with lowest recruitment cost and hence increase the marginal cost of labor.

3.6.4 Government Wedge, $\omega_{g,t}$

Although the government wedge is not directly linked to the credit crunch per se, it is worth mentioning how government expenditure evolved in Europe during the post-crisis slump period. In November 2008 the European Commission proposed a 200 billion Euros European Economic Recovery Plan and recommended EU member states to implement national expenditure plans approximately equal to 1.2 percent of GDP. This should increase government wedges and increase output through an increase in aggregate demand. However, several European countries countered these plans later on and introduced fiscal austerity measures in fear of the increasing government debt. Fiscal consolidation should have the opposite effect on GDP from that of the fiscal stimulus plan.

4 Quantitative Analysis

The Business Cycle Accounting procedure follows Chari, Kehoe and McGrattan (2007). In the first step parameter values are obtained through calibration and structural estimation using macroeconomic data. In the second step the model is solved numerically through linear solution methods. In the third step, wedges are backed out using the linearized decision rules and linearly detrended data. In the last step we plug in one wedge at a time and simulate the model in order to decompose the business cycle fluctuations into the contributions of each wedge.

4.1 Calibration

Table 2 shows the list of parameters we calibrate in order for the model to match data over the 1995Q1-2007Q4 period which we define as the pre-crisis period.[11] All parameters are country-specific and are calibrated to data of each country.[12] We report the average value and the highest and lowest among the 30 countries. The list of country-specific parameter values are available upon request.

Table 2. Calibrated Parameters

Parameter	**Description**	Average	Max	Min
δ	Depreciation rate	0.010	0.016	0.004
θ	Capital share	0.413	0.553	0.215
Λ	Growth trend	0.010	0.018	0.004
$\widehat{\beta}$	Subjective discount factor	0.976	0.993	0.909
ψ	Preference weight	0.302	0.416	0.186

The depreciation rate δ is calibrated to match the capital law-of-motion:

$$\delta_t = \frac{I_t}{K_t} + 1 - \frac{K_{t+1}}{K_t},$$

[11] The last period before the crisis is estimated through the Bai-Perron multiple unknown breakpoint test. The estimated breakpoint was not the same for every country so we used the most common breakpoint 2007Q4 in order to assume conformity.

[12] There are several countries with data availability issues. Bulgaria and Malta do not have any data for 1995Q1-1996Q4 and 1995Q1-1999Q4 respectively. Estonia and Latvia do not have labor data for 1995Q1-1999Q4.

to the average capital stock and investment data of Penn World Tables 8.0. Since the data is in annual frequency, we divide the average annual depreciation rate by 4 in order to obtain the average quarterly rate of depreciation.

The capital share θ is calibrated to match the labor share data computed by the method of Gollin (2002). First, the naïve labor income share is computed as

$$1 - \theta^n = \frac{\textit{Compensation of Employees}}{\textit{GDI - Taxes on Production and Imports less Subsidies}}.$$

Then, the labor share of income is adjusting for self-employed workers:

$$1 - \theta = (1 - \theta^n)\frac{\textit{Total Employment}}{\textit{Number of Employees}}.$$

The data for compensation of employees, taxes on production and imports less subsidies, and employees are obtained from Eurostat.

The growth trend Λ is computed as the average quarterly growth rate of total GDP. This consists of the average growth of population and the labor augmenting technical progress.

The subjective discount factor $\widehat{\beta}$ is calibrated to match the steady-state capital-output ratio in the capital Euler equation to that in data as

$$\widehat{\beta} = \frac{1}{\theta\frac{y}{k} + 1 - \delta}.$$

Notice that for convenience we have define the discount factor as

$$\widehat{\beta} = \frac{\beta}{\Lambda}.$$

The preference weight parameter ψ is calibrated to match the steady state labor input level in the labor first order condition to that in data as

$$\psi = \frac{1}{(1-\theta) * \frac{y}{c} * \frac{1-h}{h} + 1}.$$

We assume that the available working hours is 14 hours per day and normalize total hours worked per quarter h as

$$h = \frac{\text{total hours worked}}{\text{adult population} \times 14 \times \frac{365}{4}}.$$

4.2 Estimation

In the case of efficiency, labor, and government wedges, the values can be computed directly using data. In the case of the investment wedge, however, it is not so simple because as seen in equation (8) current investment wedges depend on expected future values of the economy's variables in the future. It follows that in order to compute the investment wedge in time t, we need to understand the stochastic process governing economic variables to make inferences about how the economy is going to behave in subsequent periods. Therefore we structurally estimate the stochastic process of the wedges treating the investment wedges as a latent variable.

The estimation is based on a linearized state space model

$$\begin{aligned} X_{t+1} &= \Omega X_t + \Xi \varepsilon_{t+1} \\ Q_t &= \Theta X_t + \eta_t. \end{aligned}$$

The vectors X_t and Q_t include the state variables $X_t = \left(\widetilde{k}_t, \widetilde{\omega_{e,t}}, \widetilde{\omega_{g,t}}, \widetilde{\omega_{i,t}}, \widetilde{\omega_{h,t}}\right)'$, and non-state variables $Q_t = \left(\widetilde{y}_t, \widetilde{c}_t, \widetilde{i}_t, \widetilde{h}_t\right)'$. We assume that the measurement error in the measurement equation η_t is equal to zero for all periods.

In the original CKM (2007) paper, Maximum Likelihood Estimation is used to estimate the parameters. It turns out that the MLE results are not reliable for almost all countries in our data set due to the flatness of the likelihood function. In order to avoid this issue, we applied the Bayesian method with Dynare as described in Adjemian et al (2011). The estimation priors are listed in Table 3 where P_{jj} and P_{jk} stand for the diagonal and off-diagonal terms in the transition matrix P while σ_j and $corr(\varepsilon_j, \varepsilon_k)$ stand for the standard deviation and cross-correlations of the error terms.

Table 3. Estimation Priors

Parameter	**Distribution**	Mean	Std
P_{jj}	Beta	0.90	0.05
P_{jk}	Normal	0	0.2
σ_j	Inverse Gamma	0.010	∞
$corr(\varepsilon_j, \varepsilon_k)$	Normal	0	0.3

4.3 Accounting Results

Given the parameter levels obtained through calibration and estimation, we define the linearized state space representation of the model as follows:

$$\begin{aligned} \widetilde{k_{t+1}} &= A\widetilde{k_t} + B\widetilde{\omega}_t, \\ \widetilde{v_t} &= C\widetilde{k_t} + D\widetilde{\omega}_t, \end{aligned} \tag{10}$$

where $v_t = (y_t, c_t, i_t, h_t)'$. The decision rule matrices A, B, C, D are solved through a standard linear solution method implemented by Uhlig (1999).

We assume that the economy is at steady state in 2007Q4 so that $\widetilde{k_{2007Q4}} = 0$. Then, we can compute the full series of capital stock from the capital law of motion

$$\Lambda\widetilde{k_{t+1}} = \frac{i}{k}\widetilde{i_t} + (1-\delta)\widetilde{k_t}.$$

starting from $t = 2007Q4$ given that $\widetilde{i_t}$ is observable.

From the decision rules of the observable variables (10) we can compute the wedges for all periods as

$$\widetilde{\omega_t} = D^{-1}\left(\widetilde{v_t} - C\widetilde{k_t}\right),$$

given that $\widetilde{v_t}$ is observable.

The simulation is conducted by plugging in each wedge one by one into the model:

$$\begin{aligned} \widetilde{k_{j,t+1}} &= A\widetilde{k_{j,t}} + B\widetilde{\omega_{j,t}}, \\ \widetilde{v_{j,t}} &= C\widetilde{k_{j,t}} + D\widetilde{\omega_{j,t}}. \end{aligned}$$

By construction, as shown in Otsu (2012) the sum of all simulated series will perfectly replicate the data fluctuations:

$$\sum_j \widetilde{v_{j,t}} = \widetilde{v}_t.$$

In the following section, we decompose the post-crisis slump of output into the contributions of each wedge:

$$cont(\omega_j) = \frac{v_{j,\widetilde{2014Q4}}}{v_{\widetilde{2014Q4}}}.$$

The contributions will sum up to one.

4.3.1 Computed Wedges

Figure 3 shows the time paths of each wedge over the 2007Q4-2014Q4 period. The solid line with circular markers is the observed cross-country mean value of output. The solid line with crossed markers is the cross-country mean value of the computed wedge. The dashed lines represent the 95% bootstrap confidence interval for the computed wedges.

At the beginning of the crisis the efficiency wedge begins its steep descent. At the end of the observation period it is almost 15% lower than its trend level and keeps on declining. The labor wedge initially jumps up slightly at the onset of the crisis, but after that it starts to fall until the beginning of 2013, where it levels off at around negative 9%. Throughout the entire data period the investment wedge does not seem to deteriorate on average. Government wedges rise during the 2008-2009 period, reflecting the fiscal stimulus policy known as the European Economy Recovery Plan, followed by a gradual decline reflecting the fiscal austerity measures. The confidence interval, however, is very wide compared to other wedges especially during the initial periods.

4.3.2 Average Simulation Results

Figure 4 shows the model's output response to each wedge.[13] The simulation with only efficiency wedges closely follows observed output performance in the post-crisis period. In the first year of the crisis the simulated output

[13] By construction feeding all 4 wedges back into the model gives us simply the observed data.

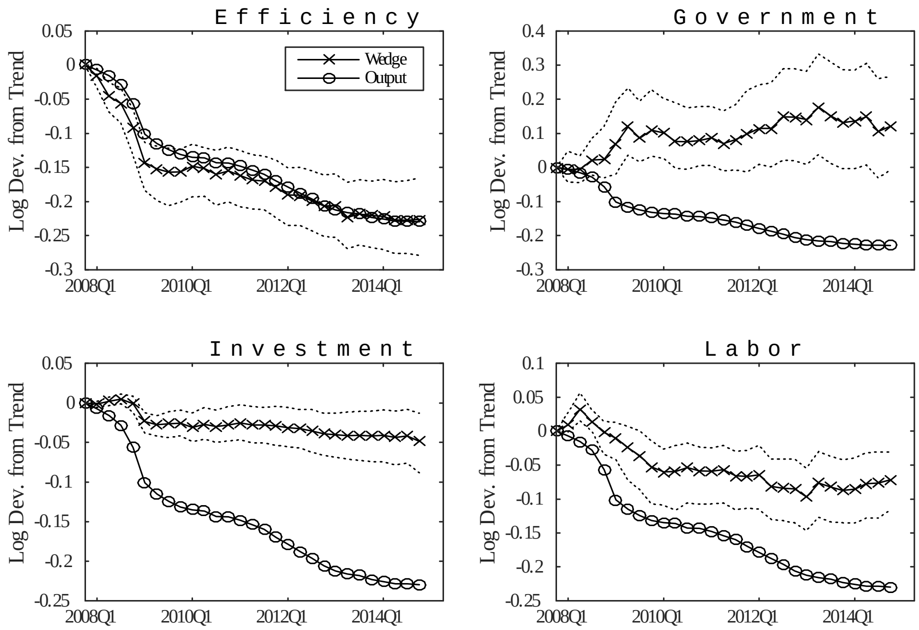

Figure 3: Computed Wedges

drop is almost identical to data. After that the gap between the simulated output and data slightly widens although the observed data is still contained by the 95% confidence interval. In 2014Q4 observed cross-country mean output is 23.5% below the 2007Q4 level, while the predicted cross-country mean output is 21.2% below it. Therefore, feeding in the efficiency wedge into the prototype model accounts for more than 90% of the observed post-crisis output drop in Europe. Feeding in the government wedge does not predict any output loss at all. Considering the investment wedge-alone economy we see that output is to increase slightly by about 1.7% in 2014Q4. Consequently, the labor wedges account for the remaining output to fall by about 4.3%.

Figure 5 shows the drop in simulated consumption vs. the observed consumption. The most important wedge in accounting for the drop consumption is the efficiency wedge. The model simulated with only efficiency wedges predicts consumption in 2014Q4 to be 17.9% below the 2007Q4 period compared to an observed fall in output of 24.5%. Again, the labor wedge closes

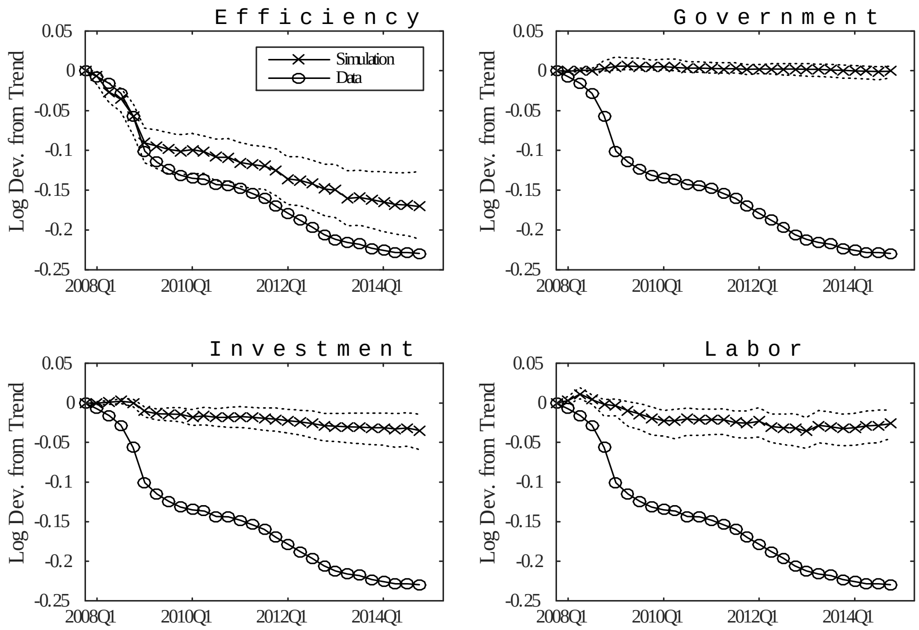

Figure 4: Accounting Result: Output

the gap by predicting a drop in consumption of about 5.7%. The models simulated with the government and the investment wedge do not predict the drop in consumption in any meaningful way.

Figure 6 shows the simulation results for investment, which emphasizes the dominance of the efficiency wedge even more. We can clearly see that the model with only efficiency wedges closely replicates the observed performance of investment in the post-crisis period until 2014Q4. Both the government and labor wedges led to slight drops over the post-crisis period by 3% and 4% respectively. However, the most interesting result is that the model with only investment wedges can only account for 5.5% of the observed investment drop.

Figure 7 shows the simulation results for labor, which gives a different picture from the previous simulations. The model with only labor wedges almost exactly replicates the observed data in labor input. The model with only efficiency wedges predicts only a drop of 2.7% in labor where the drop

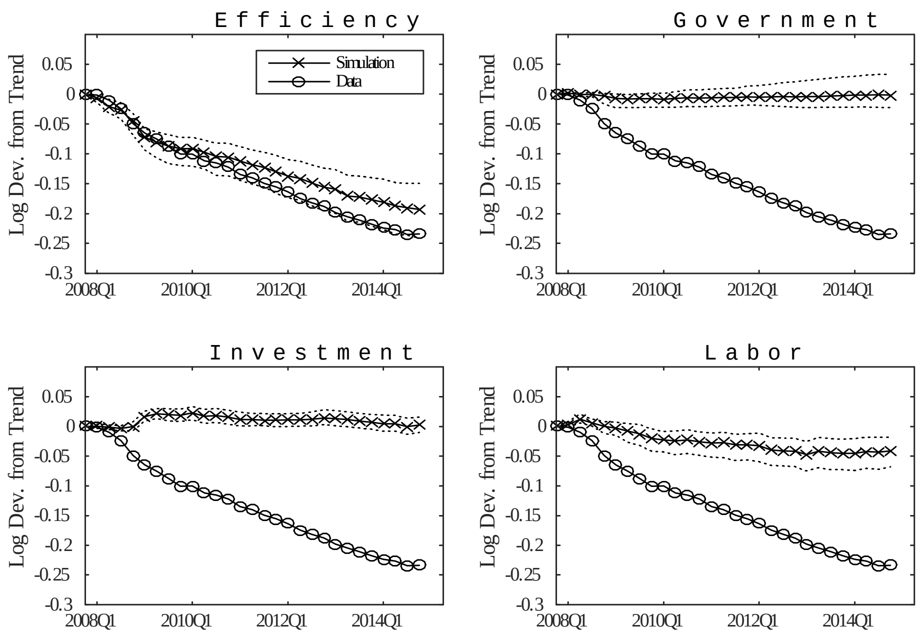

Figure 5: Accounting Result: Consumption

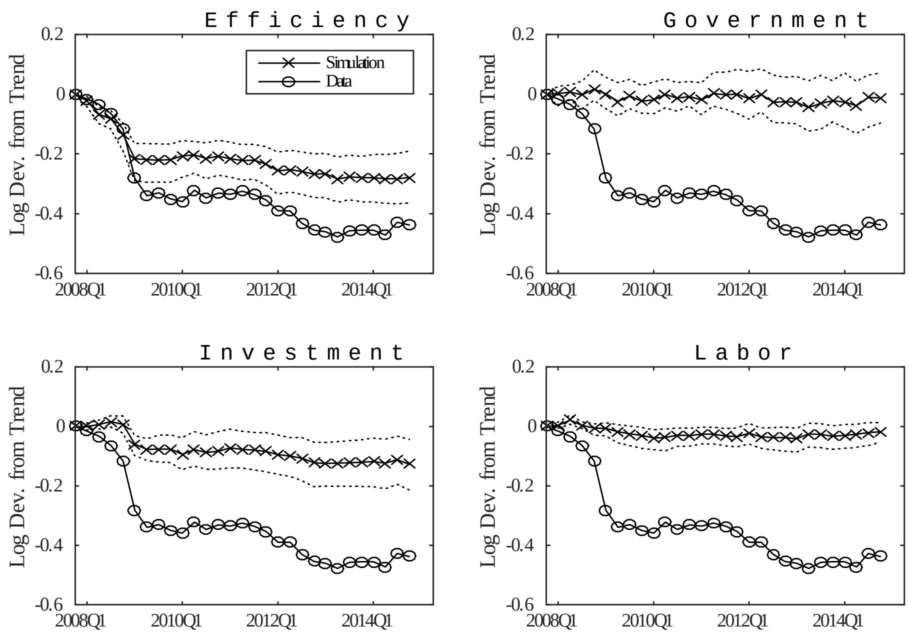

Figure 6: Accounting Result: Investment

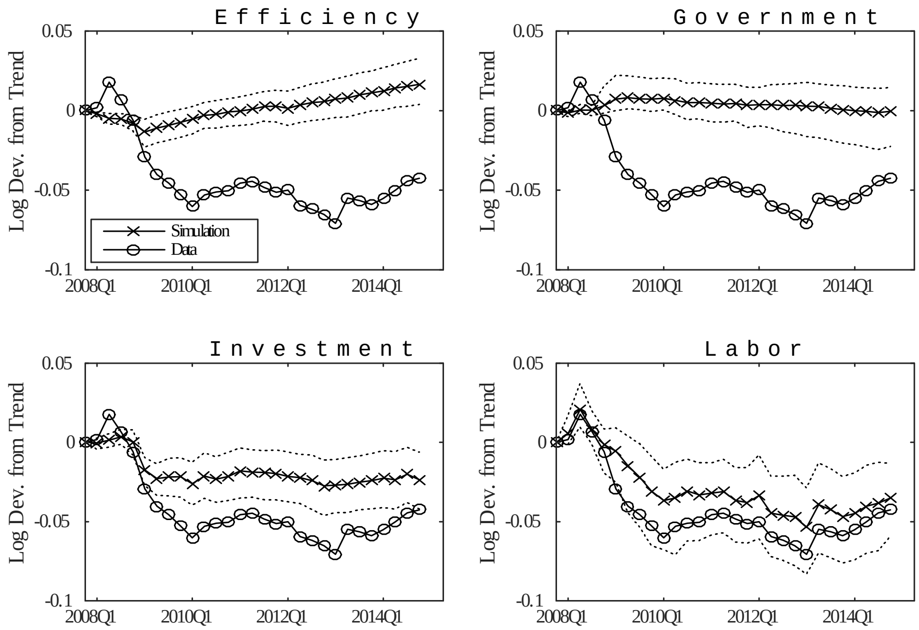

Figure 7: Accounting Result: Labor

is actually 6.0% in the data. The model with government and investment wedges predicts slight increase in labor.

4.3.3 Country Specific Simulation Results

Table 4 presents the simulation results of output for each individual country.[14] Out of the 30 European countries considered in this study, the first 18, Austria up to Spain, are the countries that adapted the Euro as their legal tender by the end of 2014. The following 9 countries, Bulgaria up to the United Kingdom, belong to the European Union, but did not adopt the Euro currency as their official medium of exchange. Iceland, Norway and Switzerland, the 3 countries at the end of the list, belong to Europe, but

[14] Country specific post-crisis behavior with respect to consumption, investment, and labor input plus the relative importance of the wedges towards these variables are available upon request.

neither accepted the Euro as their currency, nor did they join the European Union.

The first column shows the total output drop over the 2007Q4-2014Q4 period. The following columns report the contribution of each wedge on output drop measured as the simulated output drop relative to the output drop in the data. The main picture we get from this analysis is that indeed the efficiency wedge is the most important wedge explaining the drop in observed post-crisis output. However, some countries do not match that pattern. For Cyprus, Ireland, Bulgaria and Denmark the wedge that contributes most to output decline is, surprisingly, the investment wedge.[15] In these cases, the efficiency wedge comes second or even third.[16]

[15] 16 of the countries in our sample are also studied by Brinca, Chari, Kehoe and McGrattan (2016). There are some discrepancies between our country level results and theirs because i) we do not assume investment adjustment costs as they do, and ii) we use consumption as an observable instead of government wedges which they use, and iii) they use a longer data period for estimation than ours for several countries. We discuss in the appendix how investment adjustment cost and using government wedges as an observable affects our results.

[16] We also report the decomposition results for consumption, investment and labor in the appendix.

Table 4. Country-Specific Post-Crisis Behavior

Country	Output Drop (%) 2007Q4-2014Q4	Wedge Contributions (%) ω_e	ω_g	ω_i	ω_h
Austria	14.16	89.14	−1.05	7.54	4.37
Belgium	13.21	118.75	7.19	−11.93	−14.00
Cyprus	29.81	36.46	4.38	46.37	12.79
Estonia	48.73	67.53	1.65	12.94	17.88
Finland	34.32	123.45	−9.70	2.22	−15.96
France	10.90	82.38	0.87	14.68	2.07
Greece	56.06	61.80	3.43	14.91	19.85
Germany	4.69	157.47	−2.02	4.19	−59.64
Ireland	29.22	18.66	1.14	53.08	27.12
Italy	23.81	75.48	−1.37	−2.36	28.25
Latvia	48.59	75.76	1.51	19.36	3.37
Lithuania	37.04	90.83	−2.00	−10.97	22.14
Luxembourg	27.94	82.85	−10.66	24.82	2.99
Malta	*-16.61*	*119.03*	*-10.05*	*3.76*	*-12.75*
Netherlands	18.02	101.81	−2.29	−22.16	22.65
Portugal	19.10	50.67	0.66	8.21	40.46
Slovakia	25.38	85.53	2.55	6.44	5.48
Slovenia	35.31	54.14	2.99	40.80	2.08
Spain	25.40	56.75	−9.55	−0.69	53.49
Bulgaria	24.83	31.75	0.42	65.15	2.67
Czech Republic	15.22	114.36	−0.22	−3.08	−11.07
Denmark	13.59	45.85	1.44	49.50	3.20
Hungary	23.67	111.09	−10.21	−37.63	36.76
Poland	20.31	64.72	37.90	27.06	−29.67
Romania	16.88	49.18	4.27	30.07	16.49
Sweden	15.31	122.34	2.31	2.16	−26.67
United Kingdom	15.26	117.66	3.16	−31.46	10.63
Iceland	29.09	53.38	−17.72	30.02	34.32
Norway	20.31	82.75	3.02	32.64	−18.41
Switzerland	8.72	96.07	0.56	−4.32	7.69

We further assess the differences in the magnitude of output drop across countries in Table 5 by regressing output drop on the decline in efficiency wedges in each country:

$$\Delta y_n = \alpha + \sum_j \beta_j \times \Delta\omega_{j,n} + \varepsilon_n,$$

where $j = e, i, h$ and Δy_n and $\Delta\omega_{j,n}$ are the drops in output and wedges between 2007Q4 and 2014Q4 in each country n respectively. Since Malta is a clear outlier we focus on the remaining 29 countries for the regression. The results show that the greater the decline in wedges the greater the output drop. In specific, a 1% decline in efficiency, investment and labor wedges lead to declines in output by 0.534%, 0.344% and 0.437% respectively.

Table 5. Magnitude of Output Drop

Dependant Variable: Δy		
$\Delta\omega_{e,j}$	0.534**	(0.169)
$\Delta\omega_{i,j}$	0.344**	(0.075)
$\Delta\omega_{h,j}$	0.437**	(0.078)
Constant	0.052	(0.035)
R^2	0.743	
N	29	

4.3.4 Regional Differences

Following Cho and Doblas-Madrid (2013), we look into the regional differences in the experiences by dividing countries into the following groups: Eastern Europe and Western Europe, Southern Europe and Northern Europe, Euro area and Non-Euro area, Nordic countries and the rest of Europe, BeNeLux countries and the rest of Europe, British Isles and the rest of Europe. Countries defined as Eastern Europe are Bulgaria, Estonia, Latvia, Lithuania, Slovakia, Slovenia, Czech Republic, Hungary, Poland, and Romania. Countries defined as Southern Europe are Cyprus, Greece, Italy, Portugal, and Spain. Countries in the Euro are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Luxembourg, Netherlands, Portugal, Slovakia, Slovenia, and Spain. Nordic countries are Denmark, Finland, Iceland, Norway, and Sweden. BeNeLux countries are Belgium, Luxembourg, and the Netherlands. British Isles are Ireland and the United Kingdom.

We first consider the regional differences in the deterioration in wedges. The first 3 columns of Table 6 presents the estimation result of the following regression:

$$\Delta\omega_{j,n}/\Delta y_n = \alpha + \beta_d \times D_{r,n} + \varepsilon_n,$$

where $j = e, i, h$ and $D_{r,n}$ stands for the regional dummy. We normalize the size of the drops in each wedge by the drops in output so that we have a relative measure size of the wedge deterioration over the 2007-2014 period. The first column shows that Southern Europe experienced a smaller decline in labor wedges compared to other regions. The second column shows that there are no statistically significant regional differences in the declines of investment wedges. The third column shows that Southern Europe experienced larger drops in labor wedges compared to other regions.

We next consider the effects of regional differences on the decline in each wedge. The last 3 columns of Table 6 summarizes the estimation results of the following regression:

$$cont(\omega_j)_n = \alpha + \beta_d \times D_{r,n} + \varepsilon_n.$$

The fourth column in Table 6 shows that the contribution of efficiency wedges are lower in Eastern and Southern Europe than other regions. The fifth columns shows that there is no statistically significant regional differences in the contributions of investment wedges. The sixth columns show that the labor wedge contribution was greater in Southern Europe compared to other regions. This result confirms that Southern Europe is an exception in which labor wedges play quite significant roles.

Table 6. Regional Differences and the Contribution of Wedges

Regional Dummy	Dependent Variable $\Delta\omega_e/\Delta y$	$\Delta\omega_i/\Delta y$	$\Delta\omega_h/\Delta y$	$cont(\omega_e)$	$cont(\omega_i)$	$cont(\omega_h)$
Eastern	−0.336	0.204	0.300	−0.331*	0.135	0.164
Europe	(0.205)	(0.152)	(0.323)	(0.193)	(0.161)	(0.133)
Southern	−0.637**	0.094	0.921**	−0.491**	0.049	0.435**
Europe	(0.237)	(0.149)	(0.293)	(0.214)	(0.178)	(0.148)
Euro	0.020	0.128	0.016	−0.037	0.203	−0.044
Area	(0.122)	(0.247)	(0.178)	(0.149)	(0.195)	(0.103)
Nordic	−0.210	0.265	0.107	−0.227	0.240	0.042
Countries	(0.327)	(0.219)	(0.381)	(0.226)	(0.189)	(0.156)
BeNeLux	−0.155	−0.169	0.345	−0.042	−0.115	0.164
	(0.235)	(0.105)	(0.423)	(0.242)	(0.203)	(0.168)
British	−0.593	−0.361	0.833	−0.390	0.081	0.291
Isles	(0.609)	(0.507)	(0.513)	(0.274)	(0.229)	(0.190)
Constant	1.383**	0.014	−0.189**	1.090**	−0.030	−0.081
	(0.221)	(0.204)	(0.025)	(0.192)	(0.161)	(0.133)
R^2	0.065	−0.076	0.193	0.062	−0.114	0.159
N	29	29	29	29	29	29

5 Discussion: Financial Variables and the Efficiency Wedge

Given the nature of the financial crisis, we investigate the association between the cross-country differences in the decline in wedges and changes in financial variables. The financial variables we consider are the private domestic credit to GDP ratio (*DC*), non-performing loans to total loans ratio (*NPL*), the market capitalization to GDP ratio (*MC*), and the housing price index (*HPI*).[17] The data are from the World Bank World Development Indicators.

Table 7 reports the summary statistics of the financial variables. We consider both the level of these financial variables in 2007 (denoted as 07) and the change in these variables over the 2007 to 2014 period (denoted as *gr*).[18] This table shows that domestic credit and market capitalization fell

[17] Market capitalization is defined as the total value of shares in the economy.

[18] Since the Housing price index cannot be compared across countries, only consider the change in housing price index. Due to data availability, the change in market capitalization is measured over the 2013 and 2014 period.

by 0.8% and 12.9% relative to GDP respectively while non-performing loans increased by 17.0% relative to total loans after the crisis. The housing price index declined only slightly during this period on average. The decline in domestic credit being greater than that in GDP represents the credit crunch while the decline in market capitalization and rise in non-performing loans illustrates a broader concept of financial crisis.

Table 7. Financial Variables Summary Statistics

Variable	N	Mean	Median	Std. Dev.
$DC07$	29	4.503	4.470	0.520
$DCgr$	29	−0.008	−0.003	0.044
$NPL07$	26	0.198	0.369	1.007
$NPLgr$	29	0.170	0.163	0.165
$MC07$	29	4.167	4.114	0.829
$MCgr$	29	−0.129	−0.112	0.097
$HPIgr$	25	−0.006	−0.009	0.009

In order to investigate the relationship between the financial market and production efficiency, we run the following regression:

$$\Delta\omega_{j,n} = \alpha + \sum_f \beta_f \times F_{f,n} + \varepsilon_n,$$

where $F_{f,n}$ stands for the financial variables listed above. Data availability limits the sample to 23 countries.

Table 8 summarizes the regression results. The first column presents the results for efficiency wedges. This shows that countries with lower level and growth of non-performing loans, lower growth of market capitalization and the lower growth of house price index feature a higher drop in efficiency wedges. The result that countries with larger declines in domestic credit to GDP ratio do not necessarily have a larger decline in efficiency wedges is surprising.[19] This implies that the cross-country differences in the severity of the credit crunch cannot explain the cross-country differences in the magnitude of the decline in the efficiency wedge. One result that is particularly interesting is that the countries with higher growth in nonperforming loans feature a less decline in efficiency wedges. This is in fact consistent with the

[19] This does not change when we change the variable to the growth rate of domestic credit instead of the GDP ratio.

zombie lending phenomenon documented by Caballero, Hoshi and Kashyap (2008) which states that financial institutions roll over loans to insolvent low productivity firms and collect from solvent high productivity firms in order to avoid non-performing loans and maintain a superficially healthy balance sheet.[20] Therefore, a promising avenue for future research is to investigate the zombie phenomenon in Europe. In addition, we find that the cross-country differences in the declines in stock market and real estate market indicators are highly associated with the cross-country differences in the efficiency wedge declines. However, we cannot infer causality from these variables.

The second column presents the results for investment wedges. This shows that none of the financial variables are associated with the cross-country difference in investment wedges. The third column presents the results for labor wedges. This shows that countries with a larger decline in the housing price index features a greater deterioration in labor wedges. This is consistent with models with working capital constraint on labor where land serves as collateral in which a credit crunch leads to a deterioration in labor wedges by increasing the labor cost. However, the result that the severity of the credit crunch is not statistically related to the severity of the deterioration in labor wedges implies that this mechanism is not the only one operating in the labor market.

[20]The result that the cross-country differences in the level of non-performing loans are negatively associated with the cross-country differences in the decline in efficiency wedges can also be related to zombie lending. A high proportion of non-performing loans in a country can indicate the tendency of the economy to avoid zombie lending. Alternatively, this can imply that insolvent firms already exited the market in 2007 and a smaller proportion of insolvent firms are left to turn into zombies.

Table 8. Financial Variables and Wedges

	$\Delta\omega_e$	$\Delta\omega_i$	$\Delta\omega_h$
$DC07$	-0.032	0.110	0.015
	(0.073)	(0.087)	(0.079)
$DCgr$	0.575	0.633	-0.711
	(0.652)	(0.896)	(0.779)
$NPL07$	-0.057^{**}	0.010	0.024
	(0.022)	(0.025)	(0.023)
$NPLgr$	-0.335^{*}	0.124	0.042
	(0.180)	(0.240)	(0.294)
$MC07$	-0.019	-0.009	0.035
	(0.029)	(0.023)	(0.050)
$MCgr$	-1.186^{**}	-0.778	0.074
	(0.347)	(0.440)	(0.478)
$HPIgr$	-8.021^{**}	-0.936	-7.724^{*}
	(2.667)	(3.752)	(4.406)
$Constant$	0.382	-0.529	-0.201
	(0.125)	(0.394)	(0.264)
R^2	0.704	-0.142	0.423
N	23	23	23

6 Conclusion

In this paper we reviewed the economic experience of 29 European economies from the onset of the Great Recession in early 2008 until the end of 2014. We found that efficiency wedges are most important in accounting for the post-crisis slump while labor wedges play a more important role in Southern Europe than other regions. Therefore, in most part of Europe the mechanism through which the financial crisis operated during this period is a deterioration in production efficiency. This is consistent with recent literature of financial crises in which credit crunches lead to deterioration in aggregate production efficiency through misallocation across firms with heterogeneous productivity.

We further investigate the source of cross-country differences in the magnitude of efficiency wedge declines and find that countries in which non-performing loans decline more experience less decline in efficiency wedges. This implies that misallocation in the form of zombie lending is a promising explanation to the cross-country difference in efficiency loss during the European post-crisis slump. We also find that countries with higher growth in non-performing loans experienced a greater deterioration in investment wedges. Finally, countries with a greater decline in the housing price index experienced a greater deterioration in labor wedges. Further studies should focus on how non-performing loans and housing prices operate through each wedge during financial crises.

References

[1] Adjemian, S., H. Bastani, M. Juillard, F. Mihoubi, G. Perendia, M. Ratto, and S. Villemot, Dynare: Reference Manual Version 4, Dynare Working Paper Series, 1, 2011.

[2] Bernanke, B., M. Gertler and S. Gilchrist, The financial accelerator in a quantitative business cycle framework, *Handbook of Macroeconomics*, vol.1C, ch.21, 1999, pp.1341-1393.

[3] Brinca, P., Distortions in the neoclassical growth model: A crosscountry analysis. *Journal of Economic Dynamics and Control*, 47(C), 2014, pp.1-19.

[4] Brinca, P., V.V. Chari, P. Kehoe and E. McGrattan, Accounting for Business Cycles, *Handbook of Macroeconomics*, 2016, forthcoming.

[5] Buera, F. and B. Moll, Aggregate implications of a credit crunch: The importance of heterogeneity, *American Economic Journal: Macroeconomics*, 7 (3), 2015, pp.1-42.

[6] Caballero, R. T. Hoshi and A. Kashyap, Zombie Lending and Depressed Restructuring in Japan, *American Economic Review*, 98(5), 2008, pp.1943-1977.

[7] Carlstrom, C. and T. Fuerst, Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis, *American Economic Review*, 87(5), 1997, pp.893-910.

[8] Chakraborty, S., The Boom and the Bust of the Japanese Economy: A Quantitative Look at the Period 1980–2000, *Japan and the World Economy*, 21 (1), 2009, pp.116–131.

[9] Chakraborty, S. and K. Otsu, Business cycle accounting of the BRIC economies, *B.E. Journal of Macroeconomics*, 13 (1), 2013, pp.381-413.

[10] Chari, V.V., P. Kehoe, and E. McGrattan, Business Cycle Accounting, *Econometrica*, vol.75 (3), 2007, pp.781-836.

[11] Cho, D. and A. Doblas-Madrid, Business Cycle Accounting East and West: Asian Finance and the Investment Wedge, *Review of Economic Dynamics*, 16(4), 2013, pp.724-744.

[12] Gertler, M. and P. Karadi, A model of unconventional monetary policy, *Journal of Monetary Economics*, 58, 2011, pp.17-34.

[13] Gertler, M. and N. Kiyotaki, Financial Intermediation and Credit Policy in Business Cycle Analysis, *Handbook of Monetary Economics*, vol.3, ch.11, 2010, pp.547-599.

[14] Gertler, M., N. Kiyotaki and A. Queralto, Financial crises, bank risk exposure and government financial policy, *Journal of Monetary Economics*, 59, 2012, pp.S17-S34.

[15] Gilchrist, S. V. Yankov and E. Zakrajsek, Credit market shocks and economic fluctuations, *Journal of Monetary Economics*, vol.56 (4), 2009, pp.471-493.

[16] Inaba, M. and K. Nutahara, The role of investment wedge in the Carlstrom-Fuerst economy and business cycle accounting, *Economics Letters*, 105, 2009, pp.200-203.

[17] Jermann, U. and V. Quadrini, Macroeconomic effects of financial shocks, 2009, *American Economic Review*, 102 (1), pp. 238-271.

[18] Khan, A. and J. Thomas, Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity, *Journal of Political Economy*, 121 (6), 2013, pp.1055-1107.

[19] Kiyotaki, N. and J. Moore, Credit Cycles, *Journal of Political Economy,* 105(2), 1997, pp. 211-248.

[20] Klein, A. and K. Otsu, Efficiency, Distortions and Factor Utilization during the Interwar Period, University of Kent School of Economics Discussion Papers, 2013, KDPE-1317.

[21] Kobayashi, K. and M. Inaba, Business cycle accounting for the Japanese economy, *Japan and the World Economy*, 2006, 18 (4), pp.418-440.

[22] Lama, R., Accounting for output drops in Latin America, *Review of Economic Dynamics*, 14 (2), 2011, pp.295-316.

[23] Otsu, K., A neoclassical analysis of the Asian crisis: Business cycle accounting for a small open economy, *B.E. Journal of Macroeconomics*, Topics 10 (1), 2010a, Article 17.

[24] Otsu, K., International Business Cycle Accounting, University of Kent School of Economics Discussion Papers, 2010b, KDPE-1010.

[25] Otsu, K., How well can business cycle accounting account for business cycles? *Economics Bulletin*, 32 (2), 2012, pp.1774-1784.

A Sensitivity Analysis

A.1 Government Wedges

In CKM (2007) and BCKM (2016) the estimation is conducted using data of output, investment, labor and government wedges. The main reason why we use consumption data instead of the government wedge data for estimation is because for Latvia and Romania there are periods in which the government wedge turns negative due to a large trade deficit. Since we cannot take logs of negative numbers, we use the consumption data which is always positive. We also prefer using the consumption data to decompose the fluctuation in consumption in the same way as the other endogenous variables.

Technically speaking, the consumption data series can be reproduced from the linearized resource constraint up to the linearization error. Therefore, the difference in estimation results should be coming from the linearization error. When the fluctuations in government wedges and consumption are large, the linearization error might become large enough to affect the accounting results.

Figure 8 presents the simulation results for output using government wedges as an observable for countries except for Latvia and Romania.[21] In order to compute the cross-country mean, we used the benchmark results for Latvia and Romania. The results show that using government wedges as observables increases the importance of investment wedges in accounting for the post crisis slump. The general reason behind this result is that when we use the government wedge as an observable the linearized consumption series in the model drops less than that in the data. As a result, the role of investment wedges which encourage consumption over investment is overstated. However, the quantitative impact is not substantial.

A.2 Adjustment Costs

In this section, we investigate the impact of investment adjustment costs on the accounting results. We follow BCKM (2016) and assume quadratic adjustment costs in the capital accumulation equation:

$$\Lambda k_{t+1} = i_t + (1-\delta)k_t - \frac{\phi}{2}\left(\frac{i_t}{k_t} - \Phi\right)^2 k_t,$$

[21] Individual country results are available upon request.

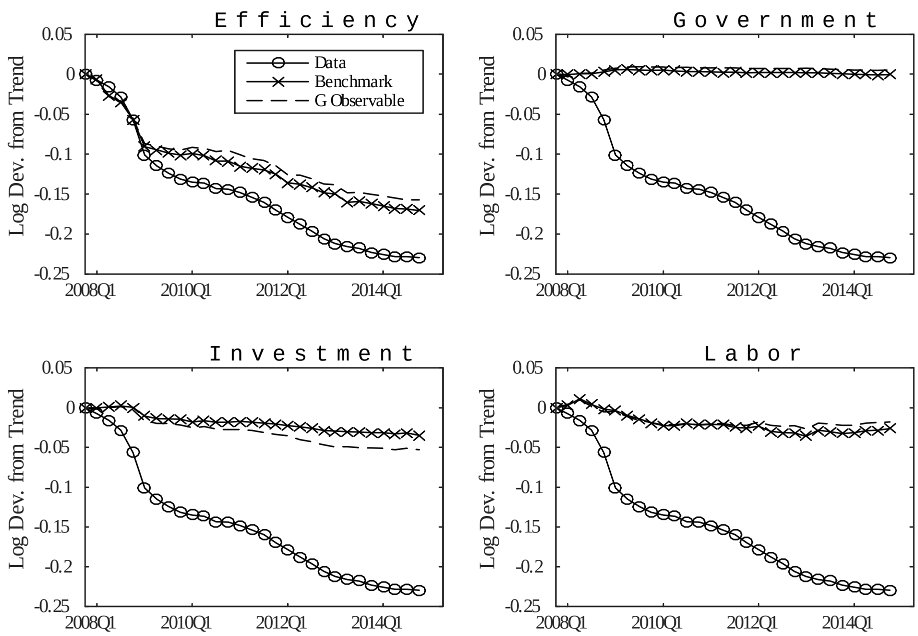

Figure 8: Accounting Result: Output with ω_g Observable

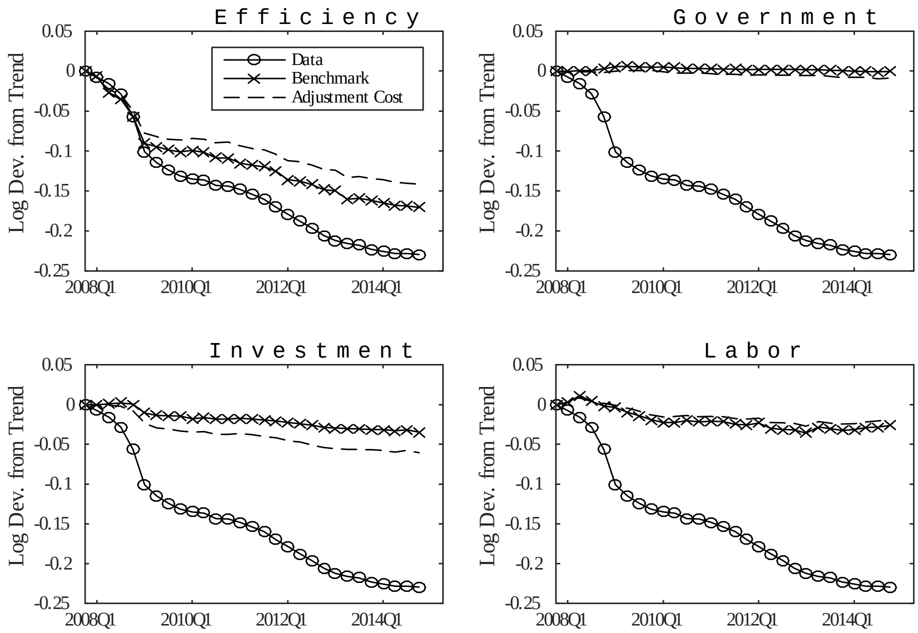

Figure 9: Accounting Result: Output with Investment Adjustment Cost

where $\Phi = \Lambda - (1 - \delta)$.

The impact of investment adjustment costs have been discussed in CKM (2007). They show that adjustment costs should systematically increase the contribution of investment wedges on output fluctuation. We find that this is true in our sample as well.

Figure 9 presents the simulation results for output from the model with investment adjustment costs.[22] We follow CKM (2007) and BCKM (2016) and set the adjustment cost parameter ϕ for each country such that the marginal Tobin's q is equal to $1/4$. The results show that the contribution of investment wedges on the post crisis slump is indeed greater when investment adjustment cost is included in the model. Nonetheless, the efficiency wedges remain the most dominant wedge in accounting for the post crisis slump in Europe.

[22]Individual country results are available upon request.

B Decomposition of Consumption, Investment and Labor

In this section, we conduct the BCA decomposition for consumption, investment and labor. Tables 9 and 10 show that efficiency wedges contribute significantly to the drop in consumption and investment in all countries except for Malta. Table 11 shows that in Germany, Slovakia, Czech Republic, Sweden and United Kingdom labor is growing relative to the pre-crisis trend. However, there is no clear pattern regarding the contributions of each wedge to the changes in labor.

Table 9. Country-Specific Post-Crisis Behavior: Consumption

Country	Consumption Drop (%) 2007Q4-2014Q4	Wedge Contributions (%) ω_e	ω_g	ω_i	ω_h
Austria	15.07	82.80	−3.02	−1.30	21.52
Belgium	10.09	130.33	−23.52	6.74	−13.55
Cyprus	22.37	55.94	14.86	−49.73	78.92
Estonia	57.13	79.13	1.75	−7.38	26.50
Finland	20.37	170.67	−42.47	−1.40	−26.81
France	9.19	108.24	−7.36	−5.04	4.16
Greece	49.62	72.49	17.30	−8.83	19.04
Germany	4.44	165.61	−1.46	2.58	−66.73
Ireland	34.59	31.96	−8.02	22.27	53.78
Italy	21.65	72.36	1.65	2.13	23.86
Latvia	49.42	85.76	14.52	−5.37	5.08
Lithuania	48.36	73.91	10.31	−9.66	25.45
Luxembourg	23.29	190.07	−122.95	0.42	32.46
Malta	*0.68*	*-2034.80*	*1303.64*	*341.63*	*489.53*
Netherlands	21.56	84.87	−5.23	15.02	5.34
Portugal	17.98	45.64	20.57	−6.07	39.87
Slovakia	31.07	66.59	24.38	6.54	2.49
Slovenia	30.66	98.38	9.58	−14.18	6.23
Spain	31.09	38.96	18.99	1.89	40.16
Bulgaria	22.37	59.77	6.90	−49.73	3.21
Czech Republic	14.65	110.23	−1.67	3.15	−11.71
Denmark	13.51	101.29	−9.49	−9.69	17.89
Hungary	39.21	47.51	15.82	15.47	21.20
Poland	6.63	270.29	−81.39	36.03	−124.94
Romania	20.73	63.84	14.41	−19.46	41.21
Sweden	10.23	203.14	−58.48	2.49	−47.15
United Kingdom	20.49	86.34	−8.65	8.97	13.34
Iceland	41.14	38.54	26.63	0.19	34.65
Norway	6.63	435.71	−178.34	−50.27	−107.11
Switzerland	7.11	87.81	2.76	−0.61	10.03

Table 10. Country-Specific Post-Crisis Behavior: Investment

Country	Investment Drop (%)	Wedge Contributions (%)			
	2007Q4-2014Q4	ω_e	ω_g	ω_i	ω_h
Austria	23.96	94.53	1.21	15.59	−11.33
Belgium	19.50	183.75	−24.34	−36.12	−23.29
Cyprus	100.71	14.81	36.24	67.77	−18.82
Estonia	71.28	61.26	−7.67	36.22	10.19
Finland	44.09	220.33	−101.88	6.91	−25.36
France	18.81	84.93	−21.08	35.20	0.95
Greece	122.77	38.26	14.24	31.61	15.90
Germany	9.50	140.83	3.59	5.37	−49.78
Ireland	38.99	10.09	−25.26	109.09	6.08
Italy	50.29	72.95	3.00	−5.98	30.02
Latvia	92.03	48.41	10.41	40.32	0.85
Lithuania	64.03	98.38	2.73	−10.42	9.31
Luxembourg	10.36	460.91	−596.69	286.18	−50.40
Malta	*21.06*	*-228.06*	*354.70*	*-33.48*	*6.84*
Netherlands	31.12	130.39	−10.70	−62.47	42.79
Portugal	53.60	30.32	34.84	12.58	22.26
Slovakia	52.89	58.69	32.89	3.05	5.36
Slovenia	85.11	16.97	26.34	57.27	−0.58
Spain	58.02	44.42	19.42	−2.64	38.80
Bulgaria	59.98	9.44	0.10	88.31	2.15
Czech Republic	24.58	126.37	−6.80	−8.14	−11.43
Denmark	25.39	20.52	−20.92	106.64	−6.24
Hungary	44.55	127.45	19.98	−82.73	35.31
Poland	27.03	38.18	17.38	61.35	−16.91
Romania	12.68	71.66	−149.86	210.68	−32.47
Sweden	18.11	228.30	−85.23	4.89	−47.96
United Kingdom	1.70	2009.76	−435.32	−1491.25	16.81
Iceland	73.15	36.36	9.26	39.94	14.43
Norway	27.03	124.18	−95.42	96.70	−25.45
Switzerland	31.25	61.11	39.75	−4.33	3.47

Table 11. Country-Specific Post-Crisis Behavior: Labor

Country	Labor Drop (%) 2007Q4-2014Q4	Wedge Contributions (%) ω_e	ω_g	ω_i	ω_h
Austria	2.79	12.61	6.83	29.45	51.10
Belgium	0.76	241.59	314.66	−213.76	−242.50
Cyprus	22.37	−4.62	−5.49	67.33	42.78
Estonia	4.49	−167.56	−2.70	143.43	126.83
Finland	2.13	235.26	164.99	32.40	−332.65
France	1.66	41.34	32.97	88.26	20.11
Greece	17.11	−4.80	−24.15	46.21	82.74
Germany	−3.91	−0.62	0.53	−1.46	101.55
Ireland	17.32	−20.29	11.25	28.27	80.78
Italy	10.30	14.94	−4.42	−6.63	96.11
Latvia	1.04	−322.13	−372.15	696.82	97.47
Lithuania	2.40	−58.08	−157.96	16.86	299.18
Luxembourg	9.70	−147.87	179.68	47.89	20.31
Malta	*-6.62*	*57.18*	*70.67*	*28.88*	*-56.73*
Netherlands	1.62	1.96	29.78	−301.60	369.86
Portugal	9.84	8.93	−21.69	16.15	96.61
Slovakia	−0.86	−82.46	561.66	32.22	−411.43
Slovenia	4.99	−151.55	−25.80	257.10	20.25
Spain	13.53	11.71	−42.38	−3.87	134.54
Bulgaria	3.33	−113.55	−29.75	195.45	47.85
Czech Republic	−2.57	−30.17	−5.12	22.44	112.86
Denmark	2.33	−213.40	42.32	230.01	41.07
Hungary	1.74	283.94	−319.50	−554.96	690.52
Poland	0.89	−366.06	1005.75	238.79	−778.47
Romania	6.03	−50.77	−23.32	93.76	80.33
Sweden	−1.54	85.29	−264.43	−3.16	282.30
United Kingdom	−1.65	−10.18	−87.75	258.26	−60.32
Iceland	5.56	−3.21	−159.60	85.77	177.04
Norway	0.89	−897.92	925.28	741.44	−668.80
Switzerland	1.78	72.43	−5.00	−11.28	43.85

C Population Weighted Results

Figure 10 presents the detrended data of each country weighted by its population weight. It is clear that the population weighted average of each variable falls less than the benchmark simple mean of them. This is because the countries that experienced the largest economic down turn such as Greece, Estonia and Latvia are small in terms of population while those that experienced a much smaller economic down turn such as Germany and France are much larger in terms of population.

Figure 11 presents the population weighted wedges. The population weighted average efficiency and labor wedge decline less than their benchmark simple mean counterparts. Government wedges increase less in the population weighted average than in the benchmark simple mean. The interesting result is the investment wedge. The population weighted average investment wedges gradually returns to the trend level while the benchmark simple mean continues to fall. This implies that investment market distortions in large countries gradually resolved while those in smaller countries remain.

Figure 12 presents the population weighted average of the accounting results for output. The results show that the main reason that the population weighted average output dropped less than the benchmark simple mean is because the efficiency wedges decline less and investment wedges recover to the trend level in the population weighted results.

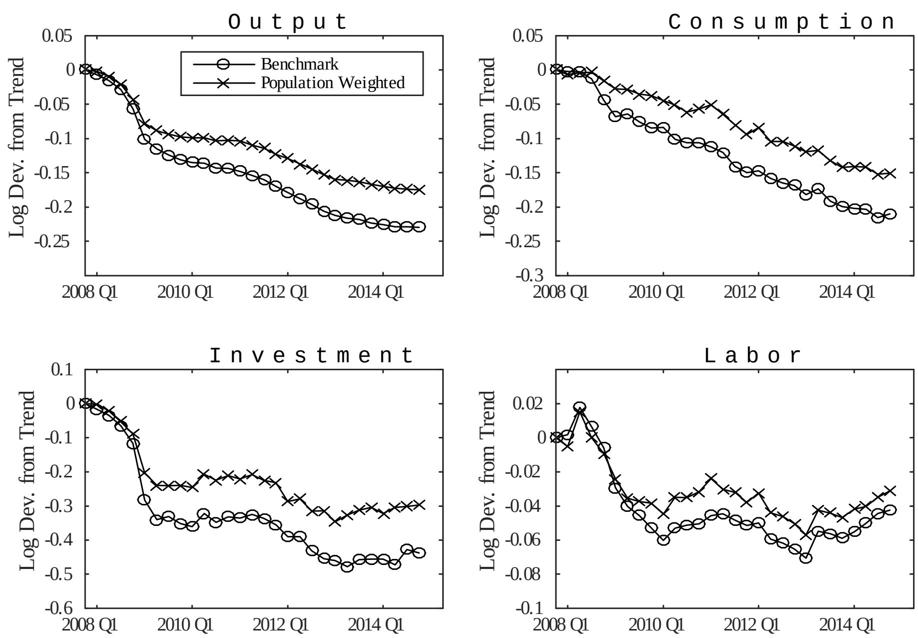

Figure 10: Population Weighted Data

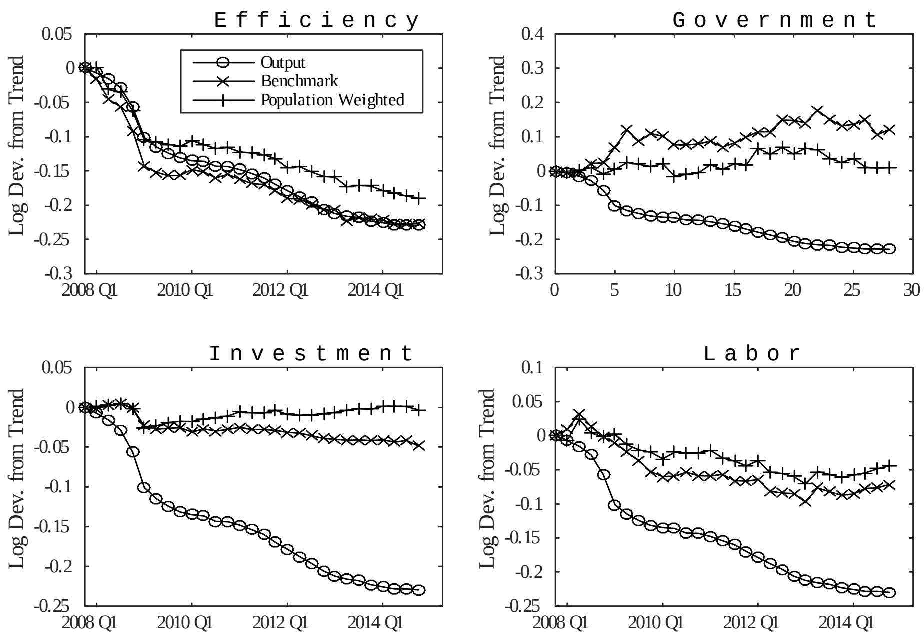

Figure 11: Population Weighted Computed Wedges

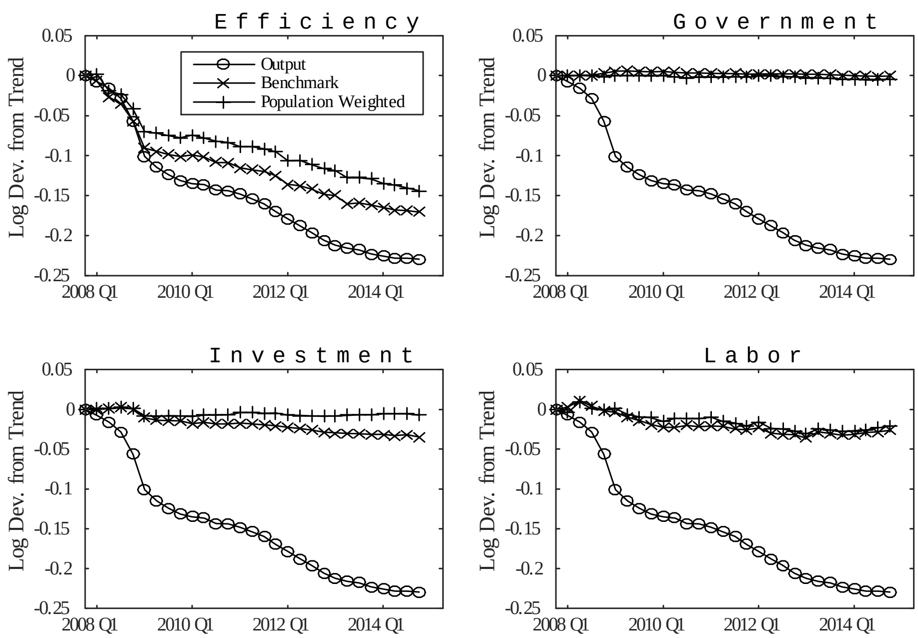

Figure 12: Population Weighted Accounting Results: Output